

Impact of magnetic resonance imaging on decision making for thoracolumbar traumatic fracture diagnosis and treatment

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Abstract

Introduction The role of magnetic resonance imaging (MRI) has recently been enhanced in the diagnosis of thoracolumbar fractures due to its ability to examine soft tissue injury.

Material and methods We conducted a prospective study to analyze the usefulness of MRI in fracture diagnosis and its influence on treatment decision making. Thirty-three patients were enrolled after suffering an acute traumatic thoracolumbar fracture. Osteoporotic or pathologic fractures were excluded. Fractures were initially classified using X-ray and CT scan following the AO classification. Afterward, a selective MRI protocol was performed with T1 and T2-weighted FS/STIR sequences. Subsequently, fractures were classified according to the TLICS system and reclassified following the AO system. Analysis was performed before and after MRI, focusing on: diagnostic changes, occult fractures and differences in treatment decision making.

Results Thirty patients (15 males, 15 females) with an average age of 39.9 years were studied. Forty-one fractures were initially diagnosed using plain X-rays and CT scans, while MRI diagnosed 50 fractures and 9 vertebral contusions. MRI modified our diagnosis in 40% of our patients

(discovering 18 occult injuries), the classification of fracture pattern in 24% of the fractures (mostly upgrading type A to type B patterns) and the therapeutic management in 16% of our patients.

Conclusions MRI seems to be a useful tool in the evaluation of thoracolumbar acute fractures, as it allows a better visualization of the posterior complex integrity and of the levels involved, offering additional information compared to traditional diagnostic tools.

Keywords Thoracolumbar fractures · Vertebral fracture diagnosis · MRI examination · Posterior ligamentous complex · MRI decision making · Classification

Introduction

Several classifications of thoracolumbar fractures have been proposed over recent decades [1] trying to grade with detail the damage to the osseous components, and more recently emphasizing the importance of soft tissue and ligament injury in fracture instability [5, 6, 10, 12, 18]. Early classifications were designed through the analysis of plain X-rays and CT scan, which are examination tools not completely able to show soft tissue anatomy [8, 10, 11, 13]. With these, the suspicion of ligament injury has to be assessed by indirect indicators such as focal kyphosis, interspinous spacing, diastasis of the facet joints or more than 50% of anterior body compression [2, 16, 17].

Some authors have drawn our attention toward the use of MR imaging to examine those soft structures anatomically [6, 12, 15]. Subsequently, we have learned that discs and ligaments play an important role in fracture stability and healing capability, and that these structures can be evaluated very well using MRI scans [2, 20]. Vaccaro et al.

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[18] have developed a novel classification system which includes the grading of posterior ligamentous complex (PLC) injury. This system has proven to be very helpful in identifying posterior instability and to set a guide for treatment. Consequently, recent studies propose that acute fractures should be analyzed with both CT and MRI scans [2, 8, 13, 14], or even only MRI scans [10, 21], to fully understand the extent of the injury and its grade of instability. However, little information is available regarding the impact and accuracy of MRI on fracture diagnosis and its help in treatment decision making.

We conducted a prospective clinical study with a series of consecutive patients admitted to our hospital after a thoracolumbar trauma. The aim was to analyze the impact and usefulness of MRI on early fracture diagnosis and its influence in treatment decision making. Our initial hypothesis was that MRI improved the identification of soft tissue damage when compared with the information that could be gained through examination using X-rays and CT imaging alone, leading to more accurate decision in fracture treatment.

Materials and methods

Between April 2008 and December 2009, a prospective study was conducted using MR imaging to analyze a consecutive series of patients who had suffered acute traumatic vertebral fractures. All patients were informed about their inclusion and the study methodology, which followed the declaration of Helsinki principles.

Inclusion criteria consisted of spinal trauma patients with acute thoracic and/or lumbar vertebral injuries, excluding those with pathological (tumors, infection, etc.) or osteoporotic fractures (considered for women over the age of 55 years or men over the age of 60 years). Fractures were diagnosed after clinical examination (local dorsal or lumbar pain, tenderness, external hematoma or palpable spinous gap) and supine anteroposterior and lateral X-rays. Neurological status was graded using the Frankel Impairment Scale proposed by the American Spinal Injury Association (ASIA).

The methodology followed four steps. Firstly, fracture pattern was examined by a senior musculoskeletal radiologist and an experienced spine surgeon, who evaluated initial radiographs and CT images, classifying the fracture according to the AO classification [9]. This classification is based on a progressive scale of morphological damage determined by the three most important mechanisms acting on the spine: compression (type A), distraction (type B) and axial torque (type C), and its further subdivisions.

Secondly, every patient underwent an MRI examination within the first week after trauma. The MR images

were obtained by means of a 1.5-Tesla system using T1-weighted and fat-suppressed (FS) T2-weighted turbo spin-echo (TSE) pulse sequences in sagittal and axial planes. In addition, a short tau inversion-recovery (STIR) pulse sequence in the sagittal plane and a T2-w fat-suppressed TSE sequence in the coronal plane were obtained. These images were used to define the morphological pattern of the fractures, the status of the intervertebral discs and especially the integrity of the posterior ligamentous complex (supraspinous and interspinous ligaments, the ligamentum flavum and both facet capsules). Ligament disruption was diagnosed when a loss of ligamentous continuity was seen (clear rupture of the “black-stripe” on T1- and FS-T2-w/STIR sequences), and ligament injury when an abnormal signal intensity within the ligament was present on T1-w and/or FS-T2-w/STIR sequences [7].

Thirdly, fractures were analyzed using the MR images by the same radiologist and spine surgeon team. Fractures were then classified according to the TLICS system [18], identifying fracture morphology as: compression, burst, translational/rotational and flexion/distraction; and PLC integrity as: intact (no visible change in the MRI signal), incompletely disrupted or indeterminate (visible change of ligament injury without full discontinuity) or disrupted (MRI signal of ligament disruption with full discontinuity). Neurological status was finally added to the classification as proposed by Vaccaro et al. [19] to complete the injury severity score (ISS). At the same time, these same MR images were used to re-classify the fractures following the AO classification described by Magerl et al. [9].

Decisions regarding the treatment of these thoracolumbar injuries were taken before and after MRI, and based on three factors: firstly, the images obtained with the examination tools, initially X-rays and CT scans and subsequently MRI, were used to analyze the degree of fracture instability of both the anterior and posterior vertebral structures, and the integrity of the soft tissues; secondly, both classification scales (AO and TLICS)—AO offers a progressive scale of damage ranging from A to C, which helps in defining fracture instability. The ISS score, developed from the TLICS, defines patients scoring more than four points as potentially unstable and having a 95% chance of requiring surgery [7]; finally, patients' particular clinical qualifiers (open fractures, multisystem trauma, comorbidities, etc.). Patients were treated either conservatively with 3 months of TLSO or with surgical instrumented fusion as required.

At the end of all this process, data were analyzed before and after MRI examination, focusing on: diagnostic changes in classification, occult injuries and differences in treatment decision.

Table 1 Patient data

Case	Gender	Age	Injury level	AO type after X-Ray/CT	AO type after MRI	MRI changes decision
1	F	31	L1	A1	A1	No-cons
2	M	32	L1	A3	B1	No-cons
3	F	37	L4	C2	C2	No-surg
4	M	33	T5/T6/T7/T8	A1/A1/O/O	A1/A1/E/E	Yes-surg
5	F	55	T10/T11/L4/L5	O/A1/A3/O	A1/A3/B2/A1	Yes-surg
6	M	60	L1	A3	B1	Yes-surg
7	F	55	T12/L1	O/A3	E/A3	Yes-surg
8	F	54	T12	A1	A1	No-cons
9	M	30	L1/L2	O/B2	E/B2	No-surg
10	F	55	T4/T5/T7/L1	A1/B1/A1/A3	B1/B1/A1/A3	Yes-surg
11	F	45	T6	A1	A1	No-cons
12	M	19	T12/L1	A1/A1	A1/A1	No-cons
13	F	55	T12	A3	A3	No-cons
14	M	60	T11	A2	A2	No-cons
15	F	55	T9/T12	O/A1	A1/A1	No-cons
16	F	24	T7	A2	A2	No-cons
17	M	32	L3	A3	A2	No-cons
18	F	10	T9/10/11/12/L1	O/A1/B1/A3/O	B1/B1/B1/A3/E	No-surg
19	M	29	T6/7/9/12/L1	O/O/O/O/C2	E/A1/A1/A1/C2	No-surg
20	M	29	T8	A1	A1	No-cons
21	M	33	T12/L1	O/A3	A1/B1	No-surg
22	M	60	L1	A1	A3	No-cons
23	M	38	L1	C2	C2	No-surg
24	F	19	T10/11/12/L1	B2/B2/A1/O	B2/B2/A1/E	No-surg
25	M	35	T4	A3	A3	No-cons
26	M	52	L2	A1	A1	No-cons
27	M	36	T8/T9/L1	O/A1/A3	A1/B2/A3	No-cons
28	F	32	T9/T12	O/A3	E/A3	No-cons
29	F	48	L2	B1	B1	No-surg
30	F	44	T9/T12	O/B1	E/B1	No-surg

M male, *F* female, *T* thoracic, *L* lumbar, *O* occult injury, *E* bone marrow edema, *AO type after MRI* AO type after Magerl et al. classification; MRI changes decision: yes or no and definitive treatment, *cons* conservative, *surg* surgical

Results

In accordance with the inclusion criteria, 33 consecutive patients were found to be eligible for enrollment. Three patients were excluded. A 29-year-old patient, with a T9 compression fracture located three levels above an anterior spinal instrumentation, placed 11 years ago due to a neuromuscular scoliosis, was excluded. It was considered secondary to osteopenia. Two patients were initially diagnosed as having a stable thoracic compression fracture (type A1) after a traumatic incident, based on clinical symptoms and radiographic suspicion of a superior end-plate disruption and local kyphosis. Both patients were finally excluded from the study because MR images ruled

out bone edema and subsequent fracture. They were considered as having Scheuermann disease.

Thirty patients (15 males, 15 females) presenting with 59 thoracolumbar acute injuries were finally included in this study. Fifty of these injuries were diagnosed as fractures, while 9 were shown to have vertebral contusions (bone marrow edema, BME) in the MRI. Mean age was 39.9 ± 13 years. Causes of injury included falling from a height (14 patients), traffic accidents (13 cases) and others (3 cases). Sixteen patients suffered injury at one level (53% of the sample), while 14 suffered multiple vertebral injuries (47%). Injuries of T10–L2 accounted for 59.2%, T2–T9 for 34% and L3–L5 for 6.8% (Table 1).

Table 2 Distribution of the initial 41 diagnosed fractures, before and after MR, according to the AO classification

AO type	X-ray-CT		MRI	
	Number	Percentage	Number	Percentage
A1	17	41.5	12	29.3
A2	2	4.9	3	7.3
A3	12	29.3	9	22
B1	4	9.8	9	22
B2	3	7.3	5	12.2
B3	0	0	0	0
C1	0	0	0	0
C2	3	7.3	3	7.3
C3	0	0	0	0

Table 3 Classification of the initial 41 diagnosed fractures, according to the TLICS system (after MRI)

	Number	Percentage
Morphology		
Compression	15	36.6
Burst	14	34.1
Translational/rotational	3	7.3
Distraction	9	21.9
Neurologic status		
Intact	39	95.1
Incomplete	2	4.9
Posterior ligamentous complex		
Intact	18	43.9
Indeterminate	10	24.4
Disrupted	13	31.7

Forty-one fractures were initially diagnosed using plain X-rays and CT scans. According to the AO classification, the distribution was as follows: 75.6% (31/41) type A, 17.1% (7/41) type B and 7.3% (3/41) type C. After MRI examination, those same 41 fractures were reclassified according to the AO system with the following distribution: 58.5% (24/41) type A fractures, 34.2% (14/41) type B and 7.3% (3/41) type C (Table 2).

In 10 of the 41 fractures (24.4%), the AO-type pattern was changed after MRI analysis. Nine of them were upgraded: seven from type A1 or A3 to type B1 or B2 due to PLC intensity changes (3 disrupted PLC and 4 indeterminate PLC) and two type A1 fractures to type A3. Only one fracture was downgraded from type A3 to A2 (Table 1).

These 41 fractures were classified using MRI according to the TLICS system (Table 3). When analyzing morphology

Table 4 Injury severity score of main fractures in a number of patients, according to the TLICS system

ISS	Number	Percentage
<4 points	14	46.7
4 points	5	16.7
>4 points	11	36.6

criteria, we discovered that 29 of the 41 fractures (70.7%) were considered to be compression or burst fractures. This group of fractures showed ten indeterminate ligaments. The other 12 fractures (29.3%) were morphologically considered to be translational or distraction fractures. In a total of 13 fractures, the PLC was diagnosed as being completely disrupted.

Using the MR images, we discovered 18 additional injuries that were not recognized with the initial X-ray and CT examination (Table 1). These occult injuries belonged to 12 patients who all suffered multiple-level injuries. Nine of these injuries presented as BME with no apparent fracture line and were considered as contusions or microtrabecular fractures. Six of them were located between T6 and T12 and three were located at L1. Another eight injuries were indeed compression fractures (type A1), mostly presenting a disrupted superior endplate. Finally, one injury was a flexion-distraction fracture (type B1) through the soft tissue, where the vertebral body was intact while the PLC was completely disrupted. This was not suspected following initial X-rays and CT scan.

When treatment decisions were taken based on X-rays and CT scans, initially nine patients were considered for operation to stabilize the fractures. The additional information provided by the MRI made us include another five patients in the surgery group (Table 1). Finally, 14 patients were operated on (46.7%), 12 by posterior only approach with instrumented fusion and 2 by a combined anterior and posterior instrumented fusion. The TLICS system injury severity score for the 30 patients is shown in Table 4.

Therefore, in five patients we modified the initial planned treatment from conservative to surgical (Table 1). In three patients (cases 5, 6, 10), the decision was taken after discovering a complete PLC disruption in the MRI, reflecting potential instability. In two patients (cases 4 and 7), the decision was taken after recognizing occult fractures and the presence of indeterminate PLC with MR imaging. In our series, the selected surgical approach based on X-rays and CT scans was not changed after MRI evaluation. However, in some patients the number of instrumented levels included in the fusion increased from that previously planned due to adjacent occult fracture or distant PLC disruption.

Discussion

This prospective study tried to analyze the potential benefits that MRI examination offers in the diagnosis of thoracolumbar fractures compared to information obtained from plain X-rays and CT scans alone, and its influence not only in classification but also in decision making. Without a doubt, X-rays and CT scans are still very useful tools in detecting osseous damage and are currently used to classify fractures in most spine centers [2, 13, 14]. The AO classification [9], which is widely used, bases its three basic fracture patterns on the analysis of these traditional examination tools [10] and still serves as a basic instrument with which to classify fractures and to decide treatment [1]. With the advent of the TLICS classification [18], and the studies using MRI to assess soft tissue damage [6, 10–12], we have become more aware of the importance of the role that discs and the posterior complex play in potential fracture instability.

MR imaging with STIR or FS-T2-w sequences is able to detect BME and, therefore, determine the acuity of an injury [2]. In the present study, we show how in patients with suspicion of fracture, due to dorsal trauma with acute pain and radiographic signs of vertebral compression or spinous diastasis, MRI can rule out the presence of acute fractures, because of the lack of bone edema and endplate disruption.

In our study, MRI detected 18 occult injuries in 12 out of 30 patients (40%), consisting of bone edema, compression fractures and distal ligament disruptions. BME injuries (represented by decreased signal on T1-w images and increased signal on T2-w, STIR and FAT-SAT [20]) cannot be seen with conventional examination tools. Compression fractures (AO type A1) should have been diagnosed with traditional tools. However, some were missed at the first examination because thoracic vertebrae were sometimes difficult to assess using plain X-rays, and CT scan was not able to show signs of minor compression (Fig. 1a, b). Distant ligament disruptions without bone injury (ligamentous chance) can only be detected with MRI scan (Fig. 2a, b). These injuries discovered by MRI can force the extension of the levels of fusion in surgically treated patients [14].

MRI is of great help in finding posterior complex injury. If the posterior tension band is injured and the load-bearing capacity of the anterior column is damaged, there is a high risk of kyphotic progression and subsequent collapse [3, 11] and therefore at least a posterior approach is recommended [11]. The AO classification establishes the differentiation between type A (anterior compression) and type B (flexion distraction) based on the integrity of the posterior elements [9]. For this reason, MRI becomes essential in distinguishing PLC disruptions although, even

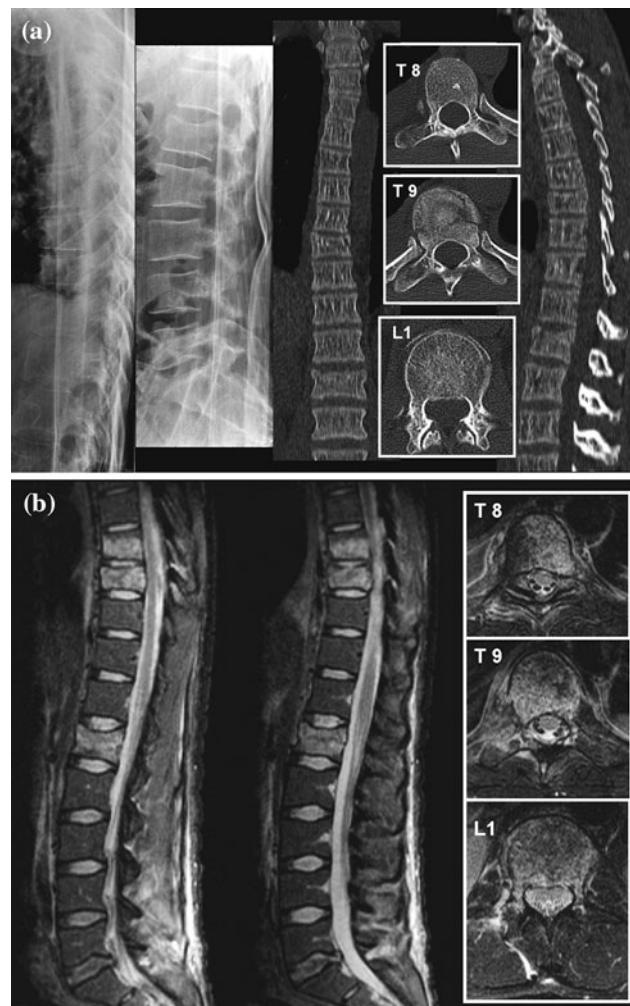


Fig. 1 **a** Case 27. Male who suffered a traffic accident. Initial X-rays show an L1 fracture and a possible T8 fracture. CT scan demonstrates a T9 fracture classified as AO type A1, and an L1 incomplete burst fracture classified as AO type A3, there is no suspicion of a T8 fracture. **b** The same case analyzed with MRI, T2-w STIR sagittal and T2-w FS axial images. An occult injury is detected in T8 with an inferior plate disruption (AO type A1). T9 fracture is upgraded to an AO type B2 because of interspinous ligament rupture. L1 shows an intact PLC, remaining as an AO type A3

when using MRI, transient forms of PLC damage still make classification difficult to assess [10].

We recommend the use of MRI as a basic examination tool to classify fractures according to AO and TLICS systems. In our results, we found that the use of MRI made us change the AO type of fracture pattern in ten cases (24%), when compared with initial X-ray/CT scan analysis. In most of the cases, this reclassification upgraded type A1 and A3 fractures to the next step of biomechanical damage, namely a flexion distraction fracture (type B); 50% of type B fractures were initially unrecognized using X-rays and CT scans. The identification of this type of fracture mostly depended on PLC interpretation after MRI. As the

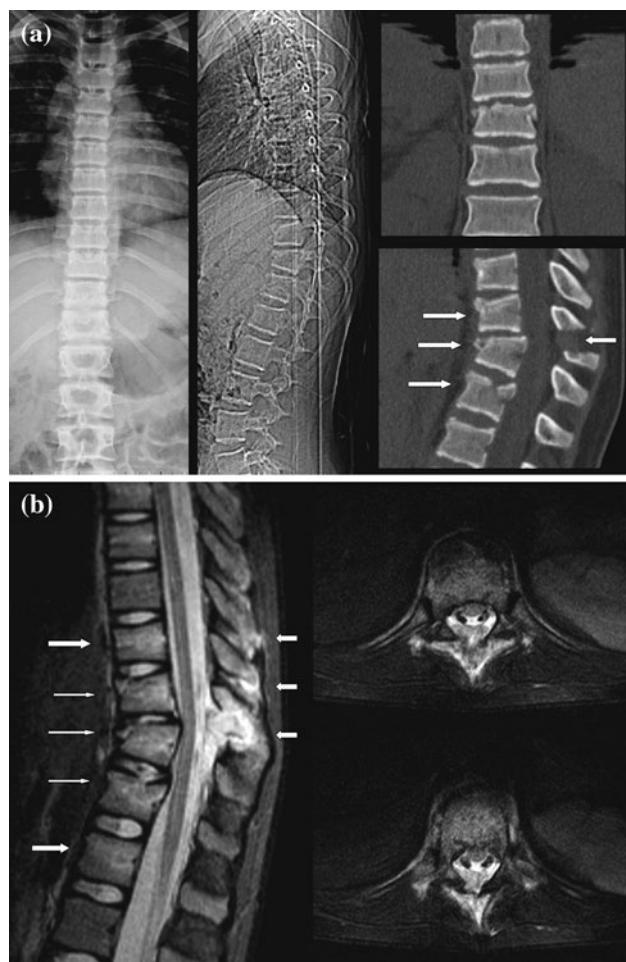


Fig. 2 **a** Case 18. A female who suffered a traffic accident. Initial X-rays show a flexion distraction thoracolumbar injury. CT scan shows a three-level vertebral fracture (see arrows) at T10 (type A1), T11 (type B1) and T12 (type A3). **b** Case 18 after MRI. T2-w STIR sagittal images show a five-level injury: T9 an occult injury, a flexion distraction (B1 or ligamentous chance); T10 a diagnostic change from A1 to B1 due to PLC disruption; T11 demonstrates a complete rupture of the PLC (B1 injury); T12 a burst fracture with intact PLC (A3) and occult bone marrow edema at L1. T2-w FS axial images show PLC disruption at T11–T12

designers of the AO classification have stated, some type B injuries are missed and classified as type A when only standard radiographs are available [9]. In their study, Leferink et al. [8] found that 30% of type B fractures were unrecognized using traditional examination tools.

The results of MRI changed our initial planned treatment in five patients, moving from a conservative to a surgical approach. This was mostly due to the potential instability shown with PLC disruption or the presence of occult injuries. MRI used for both AO and TLICS has served as a useful and basic tool in helping to define treatment.

In our opinion, patients with traumatic spinal injuries benefit from MRI examination (Table 5). T1/T2-w

Table 5 MRI new findings

	2/32 patients
Acute fracture ruled out (2)	
Occult injuries (18/59)	9 BME 8 A1 1 B1 (distant PLC disruption)
PLC injuries	35 intact 10 indeterminate 14 disrupted
Modified diagnosis (10/41 fractures)	7 A1 or A3 to B1 or B2 2 A1 to A3 1 A3 to A2
Modified treatment	5/14 surgical patients

BME bone marrow edema

sequences in axial, sagittal and coronal planes should be carried out in these patients, because they give as much osseous information as the CT scan does, especially in T1-w sequences. We agree with other authors that the best information regarding the PLC injury is offered by the FS-T2-w and STIR sequences [6, 7, 17, 20], which have improved soft tissue damage information when compared with X-rays and CT scans. However, even using these, we still have difficulties in discriminating between complete and incomplete ruptures of the posterior structures and, most of all, in differentiating self-healing disruptions from those that need to be surgically fixed to prevent a further collapse. Although controversy exists [4, 10, 11, 21], it is possible that in the future, MRI will be able to replace CT scans as the essential tool for assessing thoracolumbar fractures. We have shown how this improvement in diagnosis would lead to a more accurate decision in fracture treatment.

In conclusion, MRI seems to be a useful tool in the evaluation of thoracolumbar acute fractures as it allows a better visualization of the PLC integrity and of the levels involved. It offers additional information compared to other diagnostic tools: it modified our diagnosis in 40% of our patients, classification fracture pattern in 24% of our fractures and therapeutic management in 16% of our patients.

Conflict of interest None.

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